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Geology of the Kapit Ore Zone and Comparative Geochemistry with Minifie and Lienetz Ore Zones, Ladolam Gold Deposit, Lihir Island, Papua New Guinea

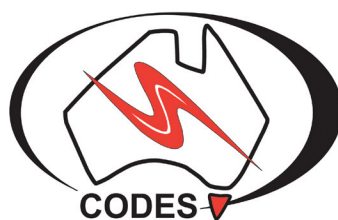
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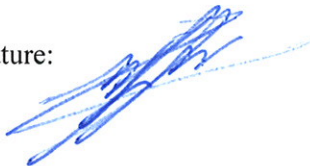


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For my grandparents

Roger Ageneau

(1924 – 2009)

and

Georgette Ageneau

(1924 – 2010)

True knowledge exists in knowing
that you know nothing.

Socrates

Abstract

The 56 Moz Ladolam gold deposit, with an average gold grade of 2.42 g/t, has previously been recognised as the world's largest known epithermal gold deposit. It is located on Lihir Island, in the New Ireland Province of Papua New Guinea, and is part of the Tabar-Lihir-Tanga-Feni chain of Pleistocene alkalic volcanoes. Alkalic magmatism occurred in an extensional tectonic regime, in a location where initial arc magmatism was related to subduction with the Manus-Kilimailau trench, but was later reactivated as a back arc due to the subduction of the Solomon Sea plate along the New Britain trench. Lihir island is made up of at least five volcanic blocks, and is surrounded by an uplifted Quaternary limestone reef. The Ladolam gold deposit is located on the eastern side of the island, in the Luise volcanic edifice. Mineralisation is localised along north-dipping structural zones. There are two large ore zones (Minifie and Lienetz) and several smaller (Kapit, Coastal, Pacific and Borefields) in a 3 km² surface area.

The Kapit ore body is hosted by diverse volcano-sedimentary and hydrothermal facies. The coherent facies include basalt, diorite and andesite. The volcanoclastic facies comprises two types of polymict matrix-supported breccia. Hydrothermal breccia facies include anhydrite-carbonate-quartz-cemented breccia and pyrite-cemented breccia.

The Kapit ore zone is characterised by five different paragenetic stages. Porphyry-style stage 1 features were not observed at Kapit, but are preserved at Lienetz and Minifie. Stage 2 anhydrite-cemented breccias and veins at Kapit are associated with porphyry-style biotite-K-feldspar-magnetite potassic alteration. Stage 3A pyrite-cemented breccia, stage 3B quartz-chalcedony-pyrite-cemented breccias and veins, and stage 3C carbonate-anhydrite-quartz-cemented breccias and veins are all associated with phyllic alteration. In contrast, stage 4 disseminated pyrite and pyrite veinlets are associated with intermediate argillic to advanced argillic alteration assemblages.

Gold at Kapit, and elsewhere at Ladolam, is contained in refractory pyrite and marcasite. The different types of pyrite and marcasite identified from the Kapit, Lienetz and Minifie ore zones are acicular, banded, colloform, euhedral, framboidal and anhedral. LA-ICPMS analyses have revealed that the colloform, framboidal, anhedral ± acicular marcasite-pyrite grains have the highest contents of gold and other trace elements.

Paragenetically, highest gold contents in Fe-sulfides occur in stage 3A (Lienetz), 3B (Kapit) and 3C (Minifie) quartz-chalcedony-pyrite-cemented breccias and veins, stage 3A (Kapit) and stage 3B (Minifie) pyrite-cemented breccias, stage 2B (Lienetz) quartz-anhydrite-barite-cemented breccias, and stage 4 (Kapit) disseminated pyrite and pyrite veinlets. At the deposit scale, Au in pyrite is positively correlated with Ag, As, Sb, Cu, Se, Pb, and Tl.

Analyses of fluid inclusions, coupled with observed mineralisation and alteration mineral assemblages from stage 2 (Kapit and Lienetz), show that mineralising fluids were relatively hot ($>250^{\circ}\text{C}$), saline (4-6 wt% NaCl eq. in average) and had near-neutral pH. In contrast, the mineralising fluids from stage 3 (Kapit, Lienetz and Minifie) were significantly cooler ($150\text{-}250^{\circ}\text{C}$), more dilute (1-4 wt% NaCl eq. in average), and acidic. Trends in fluid inclusion data are interpreted to be the result of mixing between magmatic-hydrothermal fluids (5-10 wt% NaCl eq., $>350^{\circ}\text{C}$) and steam-heated seawater (~ 3.2 wt% NaCl eq., $150\text{-}200^{\circ}\text{C}$). Distinct increases of salinity suggests that adiabatic boiling occurred during mineralisation; most likely during multiple phases of hydrothermal brecciation. Gold is likely to have been transported as a hydrosulfide complex (e.g. $\text{Au}(\text{HS})_2^-$) and boiling and/or mixing destabilised the Au-hydrosulfide complex and triggered gold precipitation. Gold contents in the mineralising fluids were up to 8 ppm, based on LA-ICPMS analyses, much higher than detected in the modern geothermal waters (up to 16 ppb). The positive correlation of Ag, Tl, As and Sb with Au in fluid inclusions imply that Ag, Tl, As and Sb were transported as hydrosulfide complexes such as $\text{H}_2\text{As}_3\text{S}_6^-$, HSb_2S_4^- , $\text{AgHS}_{(\text{aq})}$ and $\text{TiHS}_{(\text{aq})}$.

Ladolam is concluded to be a hybrid gold deposit that contains early porphyry-style alteration features, semi-massive pyritic ores hosted by hydrothermal breccias that have affinities with shallow submarine VHMS-style gold mineralisation, late-stage low sulfidation style epithermal veins and breccias and modern subaerial to submarine geothermal features. The history of the Ladolam deposit, including the Kapit, Lienetz and Minifie ore bodies is composed of a succession of catastrophic events triggering formation of different mineralised breccias and veins in an environment that evolved from submarine to subaerial after a major sector collapse event. Mineralising events can be separated into two distinct phases, transitional porphyry-VHMS (pre-sector collapse) and VHMS-epithermal (post-sector collapse).

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B - Drill core logging

C - PIMA data

D - Microprobe data

E - Sulfides LA-ICPMS data

 E1 - additionnal maps

 E2 - spot data

F - Fluid inclusions

 F1 - microthermometry

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